1. PROJECT

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Title: Pro-L\* - A probabilistic L\* mapping tool for ground observations to the magnetic equator

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2. DATASET

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Title: Pro-L\*: probabilistic hourly L\* values, with associated McIlwain Lm, magnetic field intensity B, and Cartesian coordinates for 7 global magnetic field models in the Northern Hemisphere in the period 2006-2016

Description: In radiation belt physics radial distance is often thought of by L\*, which approximates the distance from the Earth’s centre to an equatorial point (if we were to assume a dipole magnetic field). Global magnetic field models allow a subset of locations on the ground to be mapped along field lines to a location in space and transformed into L\*, provided that location maps to a closed drift path. This allows observations from ground, or low-altitude space-based platforms to be mapped into space in order to inform radiation belt modelling. In current modelling efforts a decision must therefore be made for the global magnetic field model to implement. Many data-based magnetic field models exist; however these models can significantly disagree on mapped L\* values for a single point on the ground, during both quiet times and storms. We present a state of the art probabilistic L\* mapping tool, Pro-L\*, which produces probability distributions for L\* corresponding to a given ground location.

Pro-L\* is an extensive dataset comprising 11 years’ worth (2006-2016) of hourly L\* values for 7 global magnetic field models, spanning a high resolution grid in the Northern Hemisphere where ground instruments for radiation belt studies are mostly located. Accompanying each L\* approximation, the McIlwain L, magnetic field amplitude and Cartesian location are also stored. Data was generated using the International Radiation Belt Environment Modelling library (IRBEM-Lib), a collection of FORTRAN 77 processes for radiation belt modelling which compute magnetic coordinates and drift shells using various external magnetic field models, hosted in the Python package SpacePy. The data is formatted in yearly compressed csv files, with each row a particular hour containing all of the mentioned variables for each magnetic field model, the corresponding grid point’s magnetic latitude, magnetic longitude, and magnetic local time (MLT). Therefore, each hour index appears for each grid point.

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Source(s): Data in this dataset uses OMNI data from the NASA’s OMNIWeb service (https://omniweb.gsfc.nasa.gov/), post-processed to calculate magnetic field model inputs using the method of Qin et al. (2007). The data are provided in CDF format (the NASA CDF library can be downloaded at https://cdf.gsfc.nasa.gov/) and hosted by the Virtual Radiation Belt Observatory (http://mag.gmu.edu/ftp/QinDenton/hour/merged/). These data are used as input for the IRBEM-Library, accessible from https://sourceforge.net/projects/irbem/ and included with the SpacePy package, available at https://github.com/spacepy/spacepy/

3. TERMS OF USE

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4. CONTENTS

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File names are listed as 20\*\*.csv.gz, yearly compressed csv files containing hourly data of all mentioned variables at each considered grid point.

The global magnetic field models in the dataset (also including the internal field from the International Geomagnetic Reference Field (IGRF)), in the order in which they appear for each variable, are coded as follows:

o IGRF - International Geomagnetic Reference Field

o T89 - Tsyganenko (1989)

o OPQUIET - Olson and Pfitzer (1974)

o T96 - Tsyganenko (1996)

o OSTA - Ostapenko and Maltsev (1997)

o T01STORM - Tsyganenko (2003)

o T05 - Tsyganenko and Sitnov (2005)

o T01QUIET - Tsyganenko et al. (2002)

From here on we refer to the collective group of model codes as MODEL.

There are 52 columns in total, organised via the following:

Column 0 - Time (hour) given in YYYY-MM-DD HH:MM:SS

Columns 1:8 - L\* approximations, labelled MODEL

Columns 9:16 - McIlwain L, labelled MODEL\_lm

Columns 17:24 - Magnetic field strength B at location, labelled MODEL\_b

Columns 25:32 - Mapped magnetic equator Cartesian x, labelled MODEL\_x

Columns 33:40 - Mapped magnetic equator Cartesian y, labelled MODEL\_y

Columns 41:48 - Mapped magnetic equator Cartesian z, labelled MODEL\_z

Column 49 - Magnetic latitude of grid point, labelled mlat

Column 50 - Magnetic longitude of grid point, labelled mlon

Column 51 - Magnetic local time of grid point, labelled mlt

Each file is compressed via a gzip, and was created using the Pandas package in Python (function pandas.to\_csv(Filename.csv.gz,compression=‘gzip’)). Any language capable of reading compressed csv files (or the extracted csv file) should be able to render data files.

5. METHOD and PROCESSING

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Data was generated in Python 2.7, using functions from the SpacePy (version 0.1.6, including all dependencies installed) and aacgmv2 (version 2.5.1). The SpacePy functions make use of the FORTRAN 77 processes in the IRBEM Library for considered magnetic field models, accessible at https://sourceforge.net/projects/irbem/. All data frame handling and file saving was with the pandas package (version 0.26.0). All empirical magnetic field models considered in the study require NASA OMNI data, which was installed via the most recent NASA CDF library at https://cdf.gsfc.nasa.gov/.

The process for creating data for a particular grid point in a specific hour is as follows (where locations and times are converted into SpacePy equivalents using spacepy.coordinates.Coords and spacepy.time.Ticktock, respectively):

1. The ground location is converted from magnetic to geographic coordinates using the function aacgmv2.convert\_latlon

2. The MLT of the geographic location at that time is found using aacgmv2.convert\_mlt

3. After further location and time conversions into spacepy equivalents using spacepy.coordinates.Coords and spacepy.time.Ticktock respectively, the geographic location is mapped from the ground to the minimum B point, for all magnetic field models, with the function spacepy.irbempy.find\_magequator.

4. From the mapped results, the magnetic field amplitude B and Cartesian location are saved.

5. L\* at 90 degree pitch angles is then calculated for each magnetic field model, using the previously found Cartesian locations, with the function spacepy.irbempy.irbempy.\_get\_Lstar (this version is needed for parallel computing capability). From the output for L\*, the McIlwain Lm is also withdrawn and saved.

Detailed descriptions of the L\* computation and data processing are available in the accompanying manuscript:

Thompson et al. (2019), Pro-L\* - A probabilistic L\* mapping tool for ground observations to the magnetic equator, Journal of Geophysical Research: Space Weather (In preparation)